

# **ELECTRONIC DEVICE HAVING ADJUSTABLE VCO**

## **BACKGROUND OF THE INVENTION**

### **Field of Invention**

5           The present invention relates to a voltage control oscillator. More particularly, the present invention relates to a voltage control oscillator that is adjustable.

### **Description of Related Art**

10           Oscillators are critical elements in circuit design nowadays, including both analog circuits and digital circuits. A voltage control oscillator (VCO) is a kind of oscillators that generates oscillating signals according to a reference voltage input to the voltage control oscillator. In other words, different reference voltage input determines different oscillating frequencies in voltage  
15 control oscillators.

          Even the voltage control oscillator has been developed for a long time, new designs and challenges do not stop because quality requirements of electronic equipments become higher and higher.

          Output frequency bias or phase noise of voltage control oscillators often  
20 occur due to material limitations or control difficulty of manufacturing process in mass production. Things become more difficult because such problem usually occur after assembly process of voltage control oscillators has completed. Therefore, it is a great challenge to efficiently control yield rate of voltage control oscillators.

Another common problem is that size of circuit boards are required to be more compact so that electronic devices can be made more and more smaller. It is also a great challenge to utilize every space of circuit boards to efficiently utilize every possible space.

5 In addition, more and more high frequency products, e.g. wireless phones or wireless networks, are developed for the market. While SMT (Surface Mounting Technology) is so popular, discontinuous effect response to high frequency in electrodes of such electronic devices using SMT to mount them on printed circuit boards often makes high frequency products instable.  
10 Therefore, it is more and more important to find a efficient method to manufacture high quality voltage control oscillators.

## **SUMMARY OF THE INVENTION**

It is therefore an objective of the present invention to provide a voltage  
15 control oscillator that can be fine tuned and such voltage control oscillator saves space of circuit boards so that the voltage control oscillator is particularly suitable for used in high frequency communication products with compact size.

In accordance with the foregoing and other objectives of the present invention, a first embodiment according to the present invention includes a first  
20 conductive layer and a second conductive layer that are patterned, and an insulation layer is placed between the first conductive layer and the second conductive layer.

The first conductive layer is used for supporting a portion of circuit units, e.g. transistors and resistors. The voltage control oscillator includes a  
25 resonance circuit, a coupling circuit, and oscillating circuit. In addition, the first

conductive layer is patterned to form a plurality of micro-strips for connecting the circuit units of the voltage control oscillator. Among these micro-strips, an upper micro-strip is formed in the coupling circuit while another overlapping lower micro-strip is formed in the second conductive layer. The upper  
5 micro-strip, the lower micro-strip and the insulation layer between them together form an adjustable micro-strip capacitor.

The upper micro-strip is cut by laser beam or other cutting tools during manufacturing process to adjust capacitance of the adjustable micro-strip. Because one end of the adjustable micro-strip capacitor is connected to the  
10 resonance circuit and another end is connected to the oscillating circuit, a coupling amount between the resonance circuit and the oscillating circuit is changed for adjusting the output frequency and phase noise. However, phase noise is the major concern in the first embodiment, output frequency of the voltage control oscillator is compensated by the second embodiment.

15 In the second embodiment according to the present invention, a first conductive layer and a second conductive layer are patterned in an electronic device, and an insulation layer is placed between the first conductive layer and the second conductive layer. A portion of circuit units, e.g. resistors and transistors, are supported by the first conductive layer. A voltage control  
20 oscillator includes a resonance circuit, a coupling circuit, and a oscillating circuit. In addition, the first conductive layer is patterned to produce a plurality of micro-strips for connecting the circuit units of the voltage control oscillator. Among these micro-strips, an upper micro-strip is formed in the resonance circuit while another overlapping lower micro-strip is formed in the second

conductive layer. The upper micro-strip, the lower micro-strip and the insulation layer between them together form an adjustable capacitor.

During manufacturing process, the upper micro-strip is cut in different directions by laser beam or other tools so that capacitance of the adjustable capacitor is adjusted or the adjustable capacitor react as an inductor. The adjustable capacitor is placed in the resonance circuit and one end is connected to inductors of the resonance circuit and another end is grounded. When cutting the upper micro-strip in a first direction, the adjustable capacitor react as an inductor so that the resonance frequency is decreased. In the other hand, when cutting the upper micro-strip in a second direction, capacitance of the adjustable capacitor is decreased to increase the resonance frequency of the resonance circuit so that the output frequency of the voltage control oscillator can be fine tuned.

In the third embodiment according to the present invention, the first embodiment and the second embodiment are combined. That is, adjustable micro-strip capacitors are placed in both the coupling circuit and the resonance circuit so that lowest phase noise and most precise output frequency of the voltage control oscillator is obtained during manufacturing process.

Hence, there are at least following advantages of the present invention.

Firstly, the voltage control oscillators according to the present invention utilize space of circuit boards efficiently. Secondly, problems caused by material or manufacturing process can be minimized because of such voltage control oscillator, particularly in high frequency applications. Thirdly, using adjustable micro-strip capacitor in the coupling circuit substitutes for traditional SMT capacitors and provides ability to fine tune phase noise. Also, discontinuous

phenomenon occurred in electrodes of traditional SMT units is avoided, and therefore quality of the voltage control oscillator is upgraded. Fourthly, cutting the adjustable micro-strip capacitor in different directions provides two ways frequency fine tuning ability by changing capacitance or letting capacitor  
5 reacting as an inductor. Fifthly, the voltage control oscillator can be fine tuned and therefore yield rate is increased. Six, micro-strip capacitors bring lower cost than traditional SMT capacitors and thus increase price competition of product.

It is to be understood that both the foregoing general description and the  
10 following detailed description are by examples, and are intended to provide further explanation of the invention as claimed.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

The accompanying drawings are included to provide a further  
15 understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention. In the drawings,

Fig. 1 is a schematic diagram of a voltage control oscillator;

20 Fig. 2 is a schematic diagram of circuit units of a voltage control oscillator;

Fig. 3 is a schematic diagram of a circuit board according to the first embodiment;

Fig. 4(a) is an explosion view of an adjustable capacitor according to the  
25 first embodiment;

Fig. 4(b) is an electronic diagram corresponding to Fig. 4(a);

Fig. 5(a) illustrates adjusting the adjustable capacitor of the first embodiment;

Fig. 5(b) illustrates adjusting the adjustable capacitor of the first  
5 embodiment;

Fig. 6(a) illustrates a sectional view of an adjustable capacitor of the second embodiment;

Fig. 6(b) is an explosion view of the adjustable capacitor in Fig. 6(a);

Fig. 6(c) is an schematic diagram of Fig. 6(a);

10 Fig. 7(a) illustrates adjusting the adjustable capacitor of the second embodiment in a first direction;

Fig. 7(b) illustrates adjusting the adjustable capacitor of the second embodiment in a first direction;

Fig. 7(c) illustrates adjusting the adjustable capacitor of the second  
15 embodiment in a second direction;

Fig. 7(d) illustrates adjusting the adjustable capacitor of the second embodiment in a second direction;

Fig. 8(a) illustrates the third embodiment according to the present invention; and

20 Fig. 8(b) illustrates elements in each layer of the third embodiment.

### **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are  
25 used in the drawings and the description to refer to the same or like parts.

Firstly, Fig.1 illustrates a schematic diagram of a voltage control oscillator 10. An external control voltage 17 is utilized for adjusting output frequency of the voltage control oscillator 10. As shown in Fig. 1, the voltage control oscillator 10 has a resonance circuit 11, a coupling circuit 13, and a oscillating circuit 15. The oscillating circuit 15 is used for stimulating oscillation and keep oscillating signals continue. The resonance circuit 11 limit a working frequency of the voltage control oscillator 10 within a required range. The coupling circuit 13 is used for connecting the resonance circuit 11 and the oscillating circuit 15. In addition, phase noise can be adjusted by changing the coupling amount between the resonance circuit 11 and the oscillating circuit 15 by adjusting the coupling circuit 13.

Reference is now made to Fig. 2, which illustrates a schematic diagram of a voltage control oscillator 20. The voltage control oscillator 20 has a resonance circuit 21, a coupling circuit 23, and a oscillating circuit 25.

In this example, the resonance circuit 21 is composed by a number of capacitors, inductors, an adjustable micro-strip capacitor 211, a diode with adjustable capacitance according to voltage. The coupling circuit 23 is composed of another adjustable micro-strip capacitor 231. The oscillating circuit 25 is composed of a number of capacitors, inductors, and a BJT transistor. It is to be noted that the voltage control oscillator 20 is only an example but not to limit scope of the present invention, and variations known to persons skilled in the art should still be within scope of the present invention.

Important technical features of the present invention includes design and adjustment to the adjustable capacitors 211, 231. Three embodiments are provided below for explaining related concept.

### **First Embodiment**

In this embodiment, a voltage control oscillator installed on a printed circuit board of an electronic device is fine tuned to decrease phase noise by adjusting an adjustable micro-strip capacitor, like the adjustable capacitor 231 in Fig. 2, in a coupling circuit.

Fig. 3 illustrates a circuit board structure of a voltage control oscillator 30. As shown in Fig. 3, the voltage control oscillator 30 includes a resonance circuit 31, a coupling circuit 33, and a oscillating circuit 35. Electronic diagram in Fig. 2 can be used as an example to implement the resonance circuit 31, the coupling circuit 33, and the oscillating circuit 35.

Firstly, a first conductive layer 32 is patterned to form a plurality of micro-strips. These micro-strips are conductive for connecting circuit units in the resonance circuit 31, the coupling circuit 33, and the oscillating circuit 35. Among these micro-strips, an upper micro-strip 3310 is used to be a part of a micro-strip capacitor 331 of the coupling circuit 33.

In addition, a second conductive layer 36 is patterned to form at least one lower micro-strip overlapping the upper micro-strip 3310 of the first conductive layer 32. Further, an insulation layer 34 is placed between the first conductive layer 32 and the second conductive layer 36. There is an opening in the second conductive layer 36 and conductive material is filled in the opening so that the lower micro-strip that overlaps the upper micro-strip of the first conductive layer is connected to the oscillating circuit 35 in the first conductive layer 32. With such design, the upper micro-strip 3310, the lower



micro-strip and the insulation layer 34 together form an adjustable micro-strip capacitor 331.

Then, laser beam or other cutting tools are used for partially cutting the upper micro-strip 3310 to change capacitance of the adjustable capacitor 331.

5 By changing capacitance of the adjustable capacitance 331, the electronic characteristic of the coupling circuit 33 is changed to adjust phase noise of the voltage control oscillator 30 to obtain output with lowest phase noise.

To more clearly explain the structure of the adjustable capacitor 331, reference is now made to Fig. 4(a), which is a assembling diagram of the  
10 voltage control oscillator 30 in Fig. 3.

As mentioned above, the adjustable micro-strip capacitor 331 is used a circuit unit of the coupling circuit 33 of the voltage control oscillator 30. One end 33101 of the adjustable capacitor 331 is connected to the resonance circuit 31, and the other end 33102 of the adjustable capacitor 331 is connected to the  
15 oscillating circuit 35. The adjustable capacitor 331 is composed of the upper micro-strip 3310, the lower micro-strip 3312, and the insulation layer 34. The insulation layer 34 has an opening 341 filled with conductive material 3314 for connecting the lower micro-strip to the oscillating circuit 35. In short, the electronic structure in Fig. 4(a) leads to the voltage control oscillator 30 in the  
20 schematic diagram of Fig. 4(b).

Reference is now made to Fig. 5(a) and Fig. 5(b), which illustrate two overviews of the upper micro-strip 3310 in two adjustment statuses. During manufacturing voltage control oscillator 30, laser beam or other cutting tools are used to cut the upper micro-strip 3310. Examples of cutting traces are  
25 illustrated in Fig. 5(a) and Fig. 5(b). By cutting different locations in the upper

micro-strip 3310, the adjustable micro-strip capacitor 331 has different capacitance. For example, the cutting trace shown in Fig. 5(a) brings a smaller capacitance to the adjustable capacitor 331 than the cutting trace shown in Fig. 5(b).

5           Because the adjustable micro-strip capacitor 331 is used as a circuit unit in the coupling circuit 33 of the voltage control oscillator 30, coupling amount between the resonance circuit 31 and the oscillating circuit 33 is adjustable by changing capacitance of the adjustable capacitor 331. According to different cutting traces on the micro-strip, different phase noises and output frequencies  
10   are generated. However, seeking the best coupling amount is the critical concern of this embodiment by adjusting the coupling capacitor for obtaining output with lowest phase noise. If the frequency of output signal is out of a predetermined range, the following second embodiment is used to compensate frequency bias.

## **Second Embodiment**

In this embodiment, a voltage control oscillator installed on a printed circuit board of an electronic device is adjusted by tuning an adjustable micro-strip capacitor of a resonance circuit connected in parallel. For example,  
20   the adjustable micro-strip capacitor 211 is adjusted for tuning an output frequency of the voltage control oscillator during manufacturing the voltage control oscillator.

Reference is now made to Fig. 6(a), which illustrates a schematic diagram of a circuit board structure of a voltage control oscillator 40. The  
25   voltage control oscillator 40 includes a resonance circuit, a coupling circuit, and

a oscillating circuit. The electronic diagram in Fig. (2) can be used as an example for implementing the resonance circuit, the coupling circuit, and the oscillating circuit.

Electronic structure of this embodiment is explained as follows. Firstly,  
5 a first conductive layer 42 is patterned to form a plurality of micro-strips. These micro-strips are conductive for connecting the resonance circuit, the coupling circuit, and the oscillating circuit. Among these micro-strips, a upper micro-strip 4410 is part of the resonance circuit.

A second conductive layer 46 is also patterned so that there is at least  
10 one lower micro-strip grounded and the lower micro-strip overlaps the upper micro-strip 4410 of the first conductive layer 42. In addition, an insulation layer 44 is placed between the first conductive layer 42 and the second conductive layer 46. There is an opening 481 in the insulation layer 44 and conductive material 4116 is filled in the opening 481 for connecting the lower micro-strip of  
15 the second conductive layer 46 that overlaps the upper micro-strip 4410 of the first conductive layer 42 to the oscillating circuit on the first conductive layer 42. With such design, the upper micro-strip 4410, the lower micro-strip and the insulation layer 44 together form an adjustable capacitor 411, and this adjustable capacitor 411 is placed in the resonance circuit.

20 Then, an output frequency of the voltage control oscillator is determined whether to be increased or to be decreased. When determined to decrease the output frequency, laser beam or other cutting tools are used to cut the upper micro-strip in a first direction A. With such cutting trace, the adjustable capacitor react as an inductor so that the resonance frequency of the resonance  
25 circuit is decreased. In other hand, when determined to increase the output

frequency, laser beam or other cutting tools are used to cut the upper micro-strip in a second direction B to decrease capacitance of the micro-strip 411 to increase the resonance frequency of the resonance circuit. By using such manner of this embodiment, the output frequency of the voltage control oscillator 40 can be fine tuned during manufacturing the voltage control oscillator 40.

To more clearly explain the structure of such kind of adjustable micro-strip capacitor, Fig. 6(b) is used for illustrating the structure of the adjustable capacitor 411. Because the adjustable capacitor 411 is similar to the adjustable capacitor 331 partially, elements with similar or same numerals are reference to the descriptions above in the following explanation.

The adjustable capacitor 411 is composed of an upper micro-strip 4110, a lower micro-strip 4112, and the insulation layer 44. The upper micro-strip 4110 and the lower micro-strip 4112 are generated by patterning a first conductive layer 42 and a second conductive layer 46 respectively. In this example, one end of the upper micro-strip 4110 of the adjustable capacitor 411 is connected to an inductors 49 and 43. Another end of the upper micro-strip 4110 is connected to ground via conductive material 4116 filled in an opening 481 of the insulation layer 48. In addition, Fig. 6 (c) illustrates a electronic diagram showing the adjustable capacitor 411 connecting to the inductor 49 and 43 in parallel.

Next, reference is now made to Fig. 7(a) and 7(b), which illustrates cutting the upper micro-strip of the adjustable capacitor 411 in a first direction A so that the adjustable capacitor 411 react as an inductor. With such cutting trace, the resonance frequency of the resonance circuit is changed and

consequently output frequency range of the voltage control oscillator is changed in response.

For example, the cutting trace 41103 in Fig. 7(a) on the upper micro-strip 4110 using laser beam or other cutting tools decrease output frequency of the voltage control oscillator. A even lower output frequency can be obtained by cutting the upper micro-strip with the cutting trace illustrated in Fig. 7(b).

Then, Fig. 7(c) and Fig. 7(d) illustrate cutting the upper micro-strip 4110 of the adjustable capacitor 411 in a second direction B to increase the resonance frequency when the capacitance connected in parallel is decreased by decreasing capacitance of the adjustable capacitor 411. The cutting trace 41109 in Fig. 7(d) using laser beam or other cutting tools to cut the upper micro-strip brings an even higher output frequency of the voltage control oscillator.

### **Second Embodiment**

In addition to the two embodiments above which setting adjustable capacitors on the coupling circuit and the resonance circuit respectively. another embodiment is to place adjustable capacitors on both the coupling circuit the resonance circuit.

That is, the third embodiment combines the first embodiment and the second embodiment. Reference is now made to Fig. 8(a), which illustrates a circuit board that combines the first embodiment and the second embodiment. In this circuit board, adjustable capacitors 211 and 231 that have micro-strips are placed in the coupling circuit and the resonance circuit of the voltage control oscillator. The adjustable micro-strip capacitor 211 can be cut in different

locations for providing different coupling amount to obtain lowest phase noise. The adjustable capacitor 231 can be cut in the X direction and/or Y direction to precisely fine tuning the output frequency of the voltage control oscillator.

Besides, Fig. 8(b) illustrates an explosion figure of Fig. 8(a) for more  
5 clearly explaining the concept of the present invention.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this  
10 invention provided they fall within the scope of the following claims and their equivalents.